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Thermal, light and oxygen characteristics in a small eutrophic warm monomictic lake (El Plateado, Valparaíso, Chile)

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Introduction

Physical processes have been recognized as important driving forces in the biology of temperate lakes (ALLANSON 1990). However, annual studies on the physical features in South American lakes have only appeared as general limnological characterizations during a year cycle. There are few data for periods greater than one year.

In a study of the zooplankton of Lake El Plateado, routine data on some physical properties were included. The results are reported here.

The study site

Lake El Plateado is located at 71°39′12″ W and 33°04′30″ S, between coastal hills that protect it against the wind. It is eutrophic (MONTECINO & CABRERA 1984) and used for recreation. Some morphometric features are shown in Table 1. The climate of the region is typically mediterranean and semi-arid. The dominant wind generally blows from the S-SE during spring-summer and from the N in winter. Annual average rainfall is about 500 mm, mean annual air temperature is 14 °C (INE 1991), and precipitation mainly falls in two or three winter months and is followed by a dry summer. Evaporation is low due to the relationship between surface area and depth (Table 1).

Table 1. Some major morphometric data on Lake El Plateado Lake. (After DOMÍNGUEZ et al. 1976).

Altitude (m.a.s.l.)	340
Surface area (m^2)	18,700
Volume (m^3)	89,589
Maximum depth (m)	11.5
Mean depth (m)	4.8
Longitude (m)	277
Maximum width (m)	124
Mean width (m)	67.8
Development of volume	0.42

Methods

Measurements were run weekly, and sometimes biweekly during winter months, from January 1993 to December 1994 in a fixed station near the area of maximum depth. Temperature and oxygen concentrations were measured every 0.5 m from the surface to the bottom using WTW LF 191 and WTW Oxi 196 with EOT 196 probes. Secchi depth was measured each time with a disk of 20 cm. During 1994, monthly PAR radiation measurements were made every 0.5 m, with a LI-COR LI 188B Quantum / Radiometer / Photometer equipped with an underwater sensor LI-COR 192SB. Based on these measurements, a non-linear regression between 1 % underwater irradiance and Secchi depth transparency was established. From temperature data, heat budgets were calculated following WETZEL & LIKENS (1991).

Results

Temperature and heat budgets

The temporal trend of isotherms (Fig. 1) show a strong summer stratification with a thermal gradient of 3 to 6 °C per meter from December to May (Fig. 2). The onset of fall turnover comes quickly, and the metalimnion disappears completely in June (Fig. 3). The heating of the surface water was faster in 1994 than in 1993, and the onset of summer stratification was also rapid and reached a definite thermocline during October.

The heat content (Fig. 4), adding data obtained from the beginning of July 1995, showed a maximum at the end of January and early February, and a minimum at the end of July and beginning of August. In Fig. 4 a shift can be seen that can be interpreted as showing increasing heat content from 1993 to 1995 in both summer and winter. The heat budgets also show an increase from 1993 to 1994, with values of 4,340 and 4,624, respectively.

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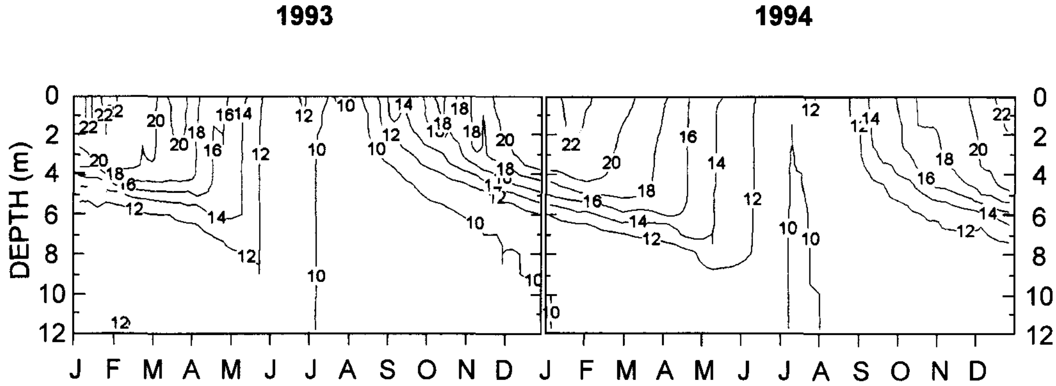

Fig. 1. Temperature (°C) isopleths in Lake El Plateado.

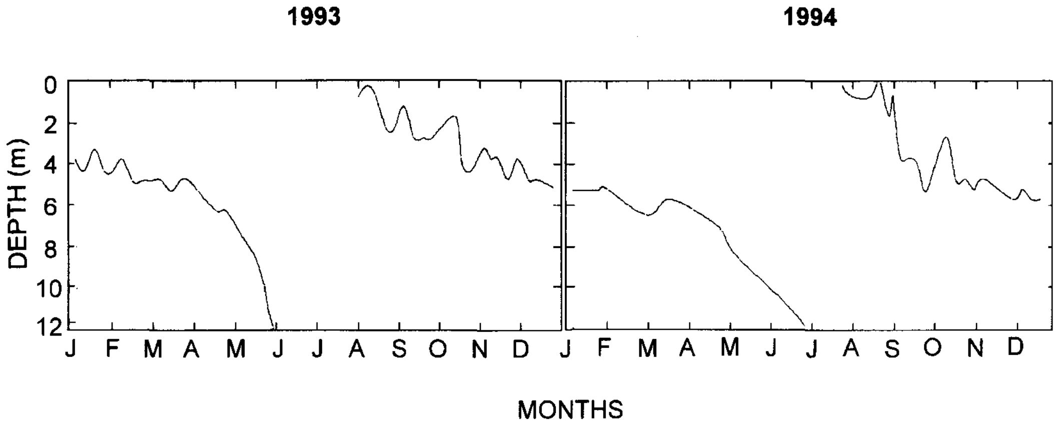

Fig. 2. Seasonal variation in thermocline depth.

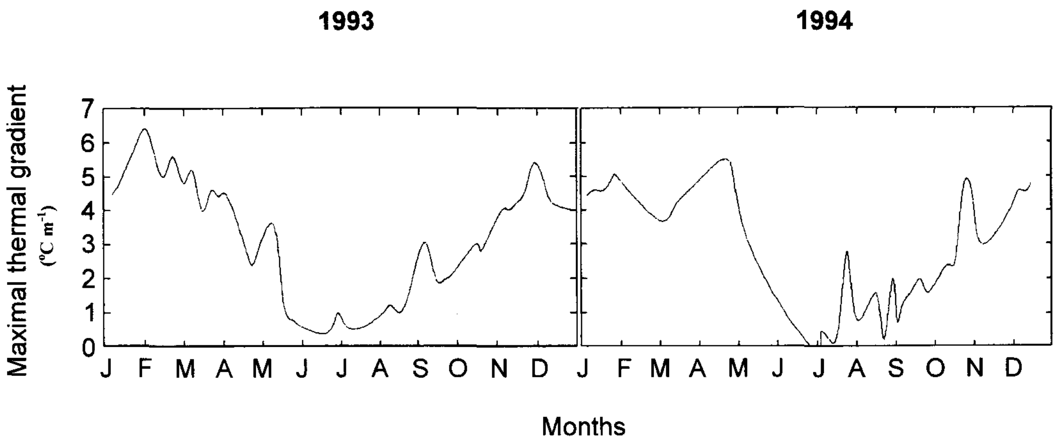

Fig. 3. Maximal thermal gradient as a measurement of intensity of thermal stratification in Lake El Plateado.

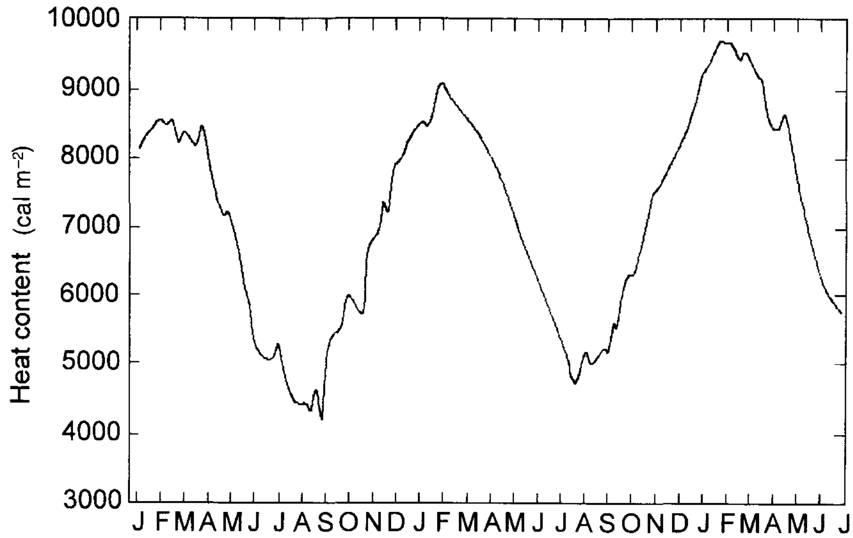

Fig. 4. Heat content (cal m^{-2}) from January 1993 to July 1995.

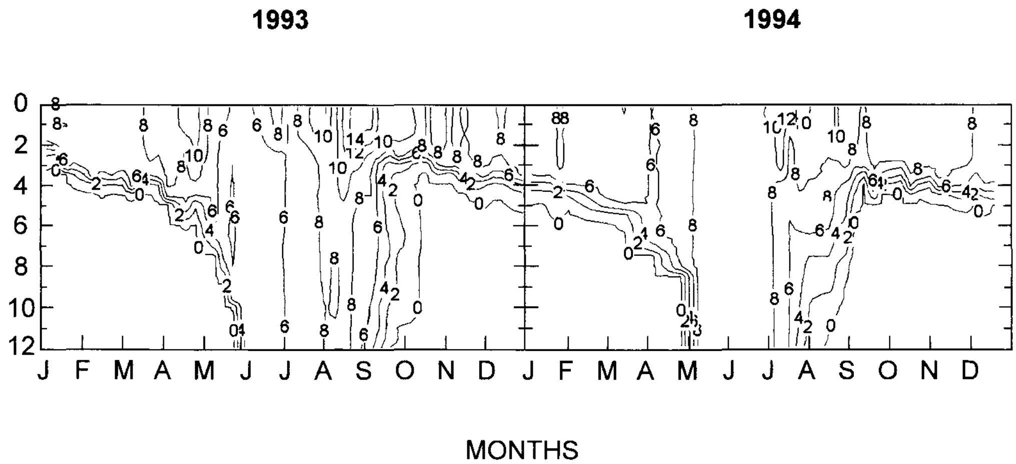

Fig. 5. Oxygen (mg L^{-1}) isopleths in Lake El Plateado.

Oxygen content

The isopleths of oxygen (Fig. 5) demonstrated an anoxic hypolimnion, and a decay in oxygen concentration in the metalimnion (Figs 2, 5). With the onset of isothermal conditions in May, the hypolimnion is quickly oxygenated (Fig. 6) and again becomes anoxic with the onset of stagnation.

Light conditions

Considering measurements of Secchi disk transparency and PAR irradiance, the regression between both measurements gives a good relationship ($r^2 = 0.94$, $p = 0.0001$ and $n = 21$). From this, the limits of the euphotic zone were established (Fig. 7). The maximum depth of the euphotic zone occurs during the period of stagnation and the minimum in winter, probably due to both the erosion of soil by rainfall, and the resuspension of sediments during holomixis.

Discussion

The results presented here showed strong vertical gradients in light, temperature, density and

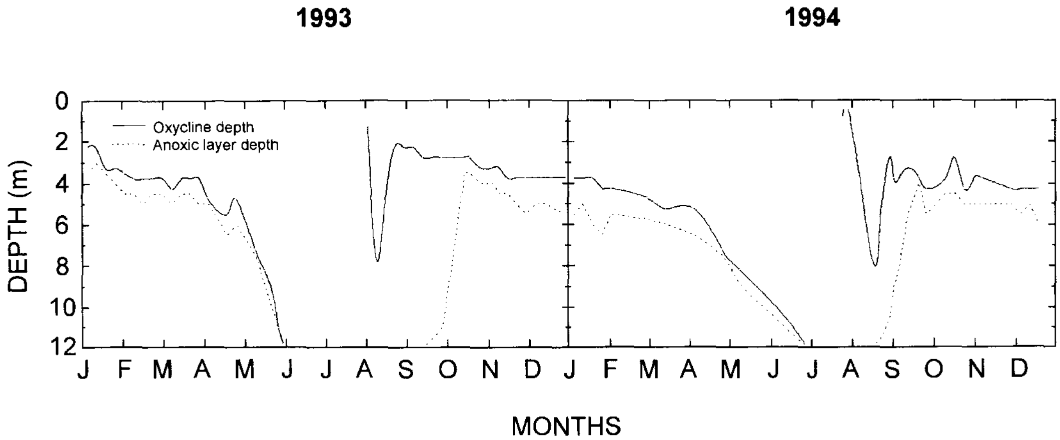

Fig. 6. Seasonal variation in oxycline depth, defined as a maximal gradient in dissolved oxygen concentration, and anoxic layer depth, defined as a minimum depth in which the dissolved oxygen concentration is below 3 mg L^{-1}.

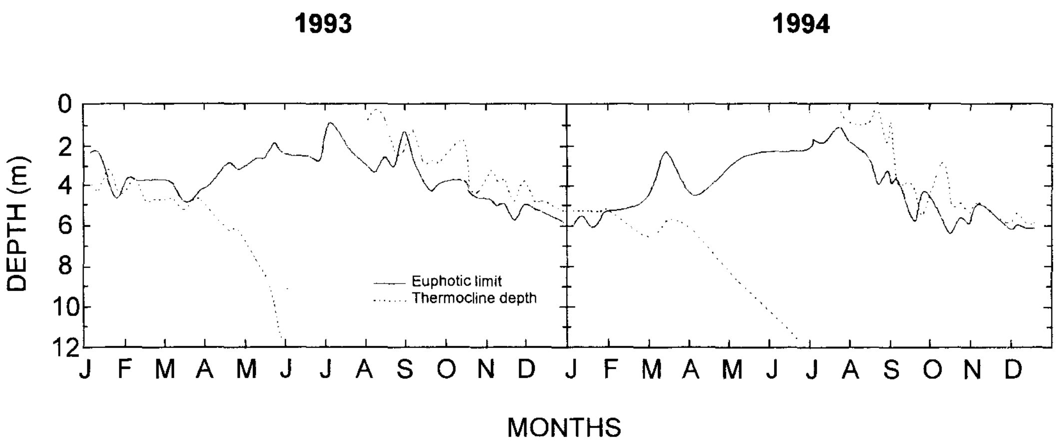

Fig. 7. Comparisons between depths of thermocline, defined as vertical position of maximum thermal gradient, and euphotic limit, calculated from regression analyses from Secchi disk depth measurements.

oxygen concentration during most of the seasonal cycle.

The establishment of the thermocline was the main perturbation for the lake immediately after winter. This was because of the steep temperature gradient that could reach up to about 6 °C per meter during the months of full stratification. This gradient is several times steeper than in other lakes at similar latitudes, e. g. Lake Kinneret (Hambright et al. 1994). In regard to heat budgets, the increasing heat content of the epi- and hypolimnion along the period is interesting. This may only be a reflection of interannual variations, but the question arises: is the lake water heating? Perhaps new measurements during following years will provide an answer and show that the lake acts as a monitor of short-term climatic changes. Continuous monitoring of South American lakes is urgently needed.

In summary, the information presented here deals with a southern hemisphere temperate lake which exhibits large physical differences over small spatial (vertical) and temporal scales. This may constitute important ecological determinants for the structure and behaviour of the lake plankton.

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